reconsideration of the subject application, particularly in view of the following remarks.

The invention claimed by Applicants is *a polymer electrolyte membrane fuel cell stack* comprising a plurality of *substantially planar* fuel cell units, each of which comprises an anode electrode, a cathode electrode and a polymer electrolyte membrane disposed between the anode electrode and the cathode electrode. A metal bipolar plate is disposed between the anode electrode of one fuel cell unit and the cathode electrode of an adjacent fuel cell unit in the fuel cell stack. The metal bipolar plate comprises a chromium-nickel *austenitic* alloy having *a nitrogen content of zero*, wherein the chromium and the nickel, on a combined basis, comprise at least about 50% by weight of the alloy.

Claims 1-17 have been rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. The Examiner indicates that the claims contain subject matter which is not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. In particular, the Examiner indicates that the claimed "zero amount of nitrogen" appears to be drawn to an absence of nitrogen insofar as no nitrogen is added to the alloy mixture. The Examiner further indicates that the specification is not enabling for an austenitic steel

alloy having no endogenous nitrogen. It is the Examiner's position that nitrogen is intrinsically present in austenitic steel alloys at a non-zero amount. For the reasons set forth herein below, Applicants respectfully disagree with the Examiner and urge that the invention is fully enabled by the specification.

Claims 1-8, 10, and 12-17 have been rejected under 35 U.S.C. 102(e) as being anticipated by or, in the alternative, under 35 U.S.C. 103(a) as being obvious over Hornung et al., U.S. Patent 6,300,001 B1 (hereinafter "the Hornung et al. patent"). This rejection is respectfully traversed.

Claims 9 and 11 have been rejected under 35 U.S.C. 103(a) as being unpatentable over the Hornung et al. patent in view of Koncar et al., U.S. Patent 5,942,347 (hereinafter "the Koncar et al. patent"). This rejection is respectfully traversed.

The Examiner indicates that these rejections are based on the reasons set forth in the Office Action sent on February 21, 2006. Applicants are only aware of an Office Action mailed 27 February 2006 and, thus, for the purposes of this response presume that it is the Office Action of 27 February 2006 to which the Examiner is referring. Applicants' arguments in response to these rejections have already been set forth in Applicants' response to the Office Action mailed 27 February 2006 and, thus, for the sake of brevity, will not be repeated.

The new issue raised by the Examiner for rejection of the subject application relates to the meaning of the term "zero amount of nitrogen" as claimed by Applicants. In response to the Office Action mailed 27 February 2006 in which the Examiner indicated that the Hornung et al. disclosure of a steel alloy having 0.02 wt. % nitrogen is readable on Applicants' claimed "zero amount of nitrogen" on the basis that a zero amount of nitrogen has a zero amount of significant figures, Applicants argued that even such a small amount of nitrogen must be considered to have an affect on the composition of the steel alloy and that to suggest that such an alloy having such a small amount of nitrogen is equivalent to an alloy having no nitrogen (a zero amount of nitrogen) would clearly be contrary to the teachings of the Hornung et al. patent. Otherwise, the Hornung et al. patent would have taught an alloy composition having no nitrogen. In the Office Action mailed 09 August 2006, the Examiner indicated agreement with Applicants' argument and withdrew the rejections.

After further consideration, the Examiner now argues that the claimed "zero amount of nitrogen" appears to be drawn to an absence of nitrogen *insofar as no nitrogen is added to the alloy mixtures*, that the Hornung et al. patent does not have a positive addition step of nitrogen, and, thus, insofar as adding nitrogen is "conventionally employed in austenitic alloys as a means for enhancing strength," the

Hornung et al. patent does not teach the addition of nitrogen and, thus, teaches or suggests a zero amount of (added) nitrogen. Applicants understand the Examiner to be arguing that the meaning of "zero amount of nitrogen" as claimed by Applicants refers to an austenitic steel alloy to which no nitrogen has been *added*, and that, because the Hornung et al. patent does not teach a positive step of nitrogen addition to the alloys described therein, then, even though no composition having a zero amount of nitrogen is taught by the Hornung et al. patent, nevertheless it suggests a zero amount of *added* nitrogen, thus anticipating or rendering Applicants' claimed invention obvious. Applicants respectfully disagree.

Firstly, if the Hornung et al. patent does not teach a positive step of nitrogen addition as indicated by the Examiner, Applicants respectfully urge that it also does not specifically teach that the nitrogen present in the disclosed steel alloys is endogenous or inherent as suggested by the Examiner. The Examiner has cited two prior art references, Sawaragi et al., U.S. Patent 5,021,215 (hereinafter "the Sawaragi et al. patent") and Hiramatsu et al., U.S. Patent 6,440,236 B1 (hereinafter "the Hiramatsu et al. patent"), as teaching that nitrogen is inherent in the composition of steel alloys. However, in both of these references, the amount of nitrogen indicated to be present in the steel alloys is minimal (250-400 ppm and less than 0.02 mass %, respectively). Applicants respectfully urge that the teachings of these two references

suggest that the higher concentrations of nitrogen (up to 1.0 wt %) in the steel alloys of the Hornung et al. patent are the result of addition.

Secondly, the basis for the Examiner's interpretation of the meaning of "zero amount of nitrogen" claimed by Applicants as referring to *added* nitrogen is the description set forth at page 8 of the specification of the subject application:

> "Nitrogen is conventionally employed in austenitic alloys as a means for enhancing strength (at the expense of formability) and as a means for preventing corrosion and pitting. Thus, it is indeed surprising and unexpected that the bi-polar separator plates of this invention exhibit superior resistance to corrosion and pitting in the acid reducing environment of the polymer electrolyte membrane fuel cell stack in spite of the absence of nitrogen in the alloy. In addition, the absence of nitrogen in the alloy enhances the formability of the alloy."

Applicants respectfully urge that the Examiner has gone beyond ascribing the *plain meaning* of the words of the claims as required by MPEP § 2111.01 *et seq.* Applicants note that there is no discussion or even hint of any steps for making the claimed austenitic stainless steel in the subject application. Thus, Applicants respectfully urge that to interpret the meaning of the claim language to include a step of nitrogen addition as suggested by the Examiner when, in fact, there is no discussion in the subject application regarding the manufacture of the austenitic steel alloy claimed by Applicants clearly goes beyond the *plain meaning* of the phrase "zero amount of nitrogen" as claimed by Applicants.

MPEP§ 2111.01 states:

> "“Plain meaning” refers to the ordinary and customary meaning given by those skilled in the art" and

> "In the absence of an express intent to impart a novel meaning to the claim terms, the words are presumed to take on the ordinary and customary meanings attributed to them by those of ordinary skill in the art."

Applicants respectfully urge that there is no expressed intent in the subject application to impart a novel meaning to the claim language "zero amount of nitrogen."

In re-applying the previously withdrawn rejections of the subject application, the Examiner indicates that the claims previously were misinterpreted as having a zero amount of nitrogen by inherent composition. The Examiner further indicates that the disclosure of the subject application is silent on the claimed austenitic alloy having a zero amount of nitrogen in the final compound. Citing the Sawaragi et al. patent and the Hiramatsu et al. patent, the Examiner argues that nitrogen is indeed inherently present in steel alloys, particularly austenitic steel alloys, at least at a non-zero amount. Accordingly, Applicants understand the Examiner's position to be that in order to overcome the rejection under 35 U.S.C. 112, first paragraph, as well as the rejections under 35 U.S.C. 102(e) and 35 U.S.C. 103(a), Applicants must present evidence that the presently claimed austenitic alloy has a zero, i.e. 0.00% of nitrogen by weight of the alloy.

Applicants respectfully urge that the interpretation of the claim language by the Examiner is not in accordance with the "plain meaning" of the language in

question as required by MPEP § 2111.01. In support of this assertion, Applicants are enclosing herewith pages from the ASM Specialty Handbook - Stainless Steels which includes "Table 1 Composition of selected standard and special stainless steels". As shown therein, *there are numerous stainless steels in which no nitrogen (0.00 wt %) is indicated to be present.* Indeed, the stainless steel designated AISI type 20Cb-3(e) shown in Table 1, for example, meets all of the requirements of the austenitic steel alloy used in the invention claimed by Applicants. Applicants respectfully urge that the ordinary and customary meaning of a zero amount of nitrogen in an austenitic steel alloy is represented by the specifications shown in the enclosed Table 1 and that one skilled in the art would interpret each of the metals indicated not to have any nitrogen as meaning they have a "zero amount of nitrogen". Accordingly, in view of this clear evidence of the plain meaning of the term "zero amount of nitrogen" as claimed by Applicants, Applicants respectfully urge that the interpretation of this term by the Examiner as referring to *added* nitrogen *or* no inherent nitrogen is clearly not in accordance with the requirements of MPEP §2111.01 regarding the application of "plain meaning" when interpreting claim language.

In summary, Applicants respectfully urge that the interpretation of the claim language of the subject application in accordance with the "plain meaning" and "ordinary and customary" requirements of MPEP § 2111.01 is fully supported by the

description and that such interpretation is fully enabled by the description. Accordingly, Applicants respectfully request withdrawal of the rejection of the subject application under 35 U.S.C. 112, first paragraph.

Regarding the rejections under 35 U.S.C. 102(e) and 35 U.S.C. 103(a) based upon the Hornung et al. patent and the Koncar et al. patent, Applicants respectfully urge that, because the Hornung et al. patent does not specifically teach the use of an austenitic steel alloy having a zero amount of nitrogen as required by Applicants' claimed invention, the Hornung et al. patent does not anticipate the invention claimed by Applicants in the manner required by 35 U.S.C. 102(e), and, because the Hornung et al. patent and the Koncar et al. patent, alone or in combination, also do not teach or suggest the use of an austenitic steel alloy having a zero amount of nitrogen as required by Applicants' claimed invention, the Hornung et al. patent and the Koncar et al. patent, alone or together, do not render Applicants' claimed invention obvious in the manner required by 35 U.S.C. 103(a).

Conclusion

Applicants intend to be fully responsive to the outstanding Office Action. If the Examiner detects any issue which the Examiner believes Applicants have not addressed in this response, Applicants urge the Examiner to contact the undersigned.

Serial No.: 10/647,610

Applicants sincerely believe that this patent application is now in condition for allowance and, thus, respectfully request early allowance.

Respectfully submitted,

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Stainless Steels

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General Introduction

STAINLESS STEELS are iron-base alloys that contain a minimum of approximately 11% Cr, the amount needed to prevent the formation of rust in unpolluted atmospheres (hence the designation *stainless*). Few stainless steels contain more than 30% Cr or less than 50% Fe. They achieve their stainless characteristics through the formation of an invisible and adherent chromium-rich oxide surface film. This oxide forms and heals itself in the presence of oxygen. Other elements added to improve particular characteristics include nickel, molybdenum, copper, titanium, aluminum, silicon, niobium, nitrogen, sulfur, and selenium. Carbon is normally present in amounts ranging from less than 0.03% to over 1.0% in certain martensitic grades. Figure 1 provides a useful summary of some of the compositional and property linkages in the stainless steel family.

With specific restrictions in certain types, the stainless steels can be shaped and fabricated in conventional ways. They can be produced and used in the as-cast condition; shapes can be produced by powder-metallurgy (P/M) techniques; cast ingots can be rolled or forged; and flat products (sheet, strip, and plate) can be produced from continuously cast slabs. The rolled product can be drawn, bent, extruded, or spun. Stainless steels can be further shaped by machining, and they can be joined by welding, brazing, soldering, and adhesive bonding. Stainless steels can also be used as an integral cladding on plain carbon or low-alloy steels as well as some nonferrous metals and alloys.

Original discoveries and developments in stainless steel technology began in England and Germany about 1910 (the historical development of stainless steels is described in the Preface to this Volume). The commercial production and use of stainless steels in the United States began in the 1920s, with Allegheny, Armco, Carpenter, Crucible, Firth-Sterling, Jessop, Ludlum, Republic, Rustless, and U.S. Steel being among the early producers.

The development of precipitation-hardenable stainless steels was spearheaded by the successful production of Stainless W by U.S. Steel in 1945. Since then, Armco, Allegheny-Ludlum, and Carpenter Technology have developed a series of precipitation-hardenable alloys.

The problem of obtaining raw materials has been a significant one, particularly in regard to nickel during the 1950s when civil wars raged in Africa and Asia, prime sources of nickel (and chromium), and Cold War politics played a role because Eastern-bloc nations were also prime sources of the element. This led to the development of a series of alloys (AISI 200 type) in which manganese and nitrogen are partially substituted for nickel. These stainless steels are being used in increasing amounts today.

New refining techniques were adopted in the early 1970s that revolutionized stainless steel melting. Most important was the argon-oxygen-decarburization (AOD) process (see the article "Melting and Refining Methods" in this Volume). The AOD and related processes, with different gas injections or partial pressure systems, permitted the ready removal of carbon without substantial loss of chromium to the slag. Furthermore, low carbon contents were readily achieved in 18% Cr alloys when using high-carbon ferrochromium in furnace charges in place of the much more expensive low-carbon ferrochromium. Major alloying elements could also be controlled more precisely: nitrogen became an easily controlled, intentional alloying element, and sulfur could be reduced to exceptionally low levels when desired. Oxygen could also be reduced to low levels and, when coupled with low sulfur, resulted in marked improvements in steel cleanliness.

During the same period, continuous casting grew in popularity throughout the steel industry, particularly in the stainless steel segment. The incentive for continuous casting was primarily economic. Piping can be confined to the last segment to be cast such that yield improvements of approximately 10% are commonly achieved. Improvements in homogeneity are also attained.

Over the years, stainless steels have become firmly established as materials for cooking utensils, fasteners, cutlery, flatware, decorative architectural hardware, and equipment for use in chemical plants, dairy and food-processing plants, health and sanitation applications, petro-

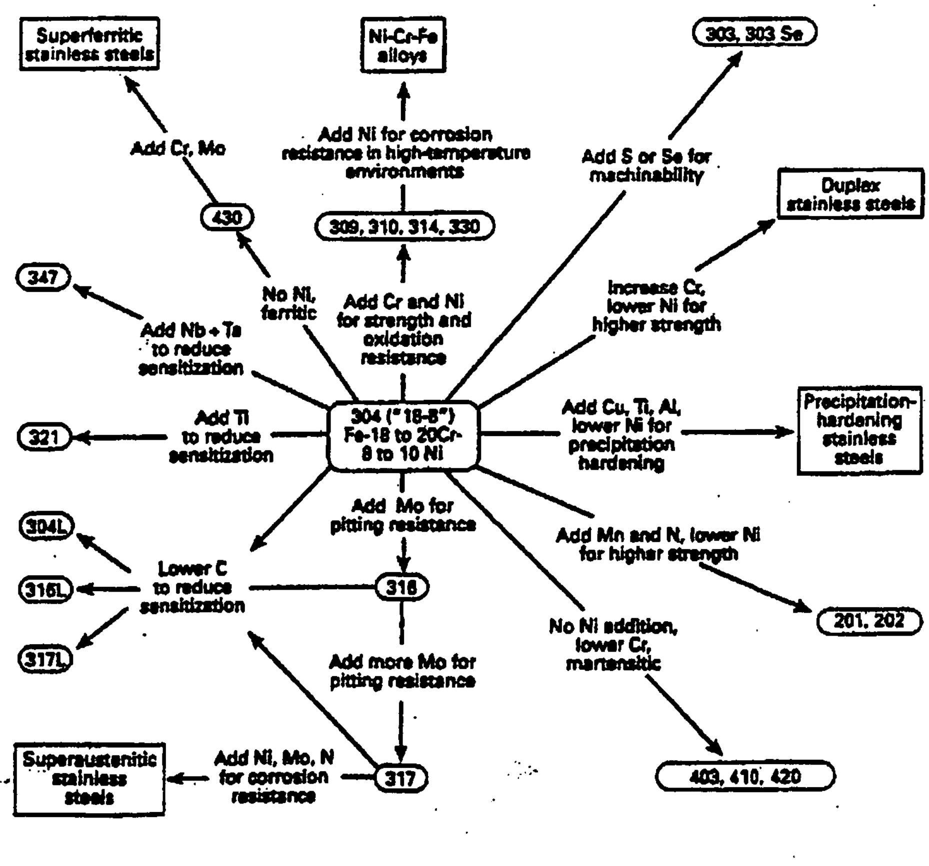

Fig. 1 Compositional and property linkages in the stainless steel family of alloys. Source: Ref 1

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able 1 Composition of selected standard and special stainless steels

NS signation	AISI type	Composition, wt% max									
		C	Mn	Si	P	S	Cr	Ni	Mo	N	Others
erritic alloys											
40500	405	0.08	1.00	1.00	0.040	0.030	11.50-14.50	...	...	...	0.10-0.30 Al
40900	409	0.08	1.00	1.00	0.045	0.045	10.50-11.75	0.50	...	...	6 × C-0.75 Ti
43000	430	0.12	1.00	1.00	0.040	0.030	16.00-18.00	...	...	...	...
43020	430F	0.12	1.25	1.00	0.060	0.15(a)	16.00-18.00	...	0.60	...	...
43023	430FSe	0.12	1.25	1.00	0.060	0.060	16.00-18.00	...	...	...	0.15 min Se
43400	434	0.12	1.00	1.00	0.040	0.030	16.00-18.00	...	0.75-1.25	...	...
44200	442	0.20	1.00	1.00	0.040	0.030	18.00-23.00	...	...	...	...
44300	443(b)	0.20	1.00	1.00	0.040	0.030	18.00-23.00	0.50	...	...	0.90-1.25 Cu
44400	444(b)	0.025	1.00	1.00	0.040	0.030	17.50-19.50	1.00	1.75-2.50	0.025	[0.20 + 4 (C + N)]-0.80 Ti + Nb
44600	446(b)	0.20	1.50	1.00	0.040	0.030	23.00-27.00	...	...	0.25	...
18200	18-2FM(c)	0.08	1.25-2.50	1.00	0.040	0.15(a)	17.50-19.50	...	1.50-2.50	...	...
artensitic alloys											
40300	403	0.15	1.00	0.50	0.040	0.030	11.50-13.00	...	...	...	...
41000	410	0.15	1.00	1.00	0.040	0.030	11.50-13.00	...	...	...	...
41400	414	0.15	1.00	1.00	0.040	0.030	11.50-13.50	1.25-2.50	...	...	...
41600	416	0.15	1.25	1.00	0.060	0.15(a)	12.00-14.00	...	0.60	...	...
41610	416 Plus X(d)	0.15	1.50-2.50	1.00	0.060	0.15(a)	12.00-14.00	...	0.60	...	...
41623	416Se	0.15	1.25	1.00	0.060	0.060	12.00-14.00	...	...	...	0.15 min Se
42000	420	0.15(a)	1.00	1.00	0.040	0.030	12.00-14.00	...	...	...	...
42010	Trim Rite(e)	0.15-0.30	1.00	1.00	0.040	0.030	13.50-15.00	0.25-1.00	0.40-1.00	...	...
42020	420F	0.15(a)	1.25	1.00	0.060	0.15(a)	12.00-14.00	...	0.60	...	...
42023	420FSe(b)	0.30-0.40	1.25	1.00	0.060	0.060	12.00-14.00	...	0.60	...	0.15 min Se; 0.60 Zr or Cu
43100	431	0.20	1.00	1.00	0.040	0.030	15.00-17.00	1.25-2.50	...	...	...
44002	440A	0.60-0.75	1.00	1.00	0.040	0.030	16.00-18.00	...	0.75	...	...
44003	440B	0.75-0.95	1.00	1.00	0.040	0.030	16.00-18.00	...	0.75	...	...
44004	440C	0.95-1.20	1.00	1.00	0.040	0.030	16.00-18.00	...	0.75	...	...
44020	440F(b)	0.95-1.20	1.25	1.00	0.040	0.10-0.35	16.00-18.00	0.75	0.40-0.60	0.08	...
44023	440FSe(b)	0.95-1.20	1.25	1.00	0.040	0.030	16.00-18.00	0.75	0.60	0.08	0.15 min Se
ustenitic alloys											
20100	201	0.15	5.50-7.50	1.00	0.060	0.030	16.00-18.00	3.50-5.50	...	0.25	...
20161	Gall-Tough(e)	0.15	4.00-6.00	3.00-4.00	0.040	0.040	15.00-18.00	4.00-6.00	...	0.08-0.20	...
20300	203EZ(f)	0.08	5.00-6.50	1.00	0.040	0.18-0.35	16.00-18.00	5.00-6.50	0.50	...	1.75-2.25 Cu
20910	22-13-5(c)	0.06	4.00-6.00	1.00	0.040	0.030	20.50-23.50	11.50-13.50	1.50-3.00	0.20-0.40	0.10-0.30 Nb; 0.10-0.30 V
21000	SCF19(e)	0.10	4.00-7.00	0.60	0.030	0.030	18.00-23.00	16.00-20.00	4.00-6.00	0.15	2.00 Cu
21300	15-15LC(e)	0.25	15.00-18.00	1.00	0.050	0.050	16.00-21.00	3.00	0.50-3.00	0.20-0.80	0.50-2.00 Cu
21800	Nitronic 60(g)	0.10	7.00-9.00	3.50-4.50	0.040	0.030	16.00-18.00	7.00-9.00	...	0.08-0.20	...
21904	21-6-9LC(c)	0.04	8.00-10.00	1.00	0.060	0.030	19.00-21.50	5.50-7.50	...	0.15-0.40	...
24100	18-2Mn(c)	0.15	11.00-14.00	1.00	0.060	0.030	16.50-19.50	0.50-2.50	...	0.20-0.45	...
28200	18-18 Plus(e)	0.15	17.00-19.00	1.00	0.045	0.030	17.00-19.00	...	0.50-1.50	0.40-0.60	0.50-1.50 Cu
..	Nitronic 30(g)	0.10	7.00-9.00	1.00	...	...	15.00-17.00	1.50-3.00	...	0.15-0.30	1.00 Cu
30100	301	0.15	2.00	1.00	0.045	0.030	16.00-18.00	6.00-8.00	...	...	...
30200	302	0.15	2.00	1.00	0.045	0.030	17.00-19.00	8.00-10.00	...	...	...
30300	303	0.15	2.00	1.00	0.20	0.15(a)	17.00-19.00	8.00-10.00	0.60	...	...
30310	303 Plus X(d)	0.15	2.50-4.50	1.00	0.20	0.25(a)	17.00-19.00	7.00-10.00	0.75	...	...
30323	303Se	0.15	2.00	1.00	0.20	0.060	17.00-19.00	8.00-10.00	...	...	0.15 min Se
30330	303 Cu(b)	0.15	2.00	1.00	0.15	0.10(a)	17.00-19.00	6.00-10.00	...	...	2.50-4.00 Cu; 0.10 Se
30400	304	0.08	2.00	1.00	0.045	0.030	18.00-20.00	8.00-10.50	...	...	...
30403	304L	0.03	2.00	1.00	0.045	0.030	18.00-20.00	8.00-12.00	...	...	...
30430	302 HQ(b)	0.10	2.00	1.00	0.045	0.030	17.00-19.00	8.00-10.00	...	...	3.00-4.00 Cu
30431	302 HQ-FM(e)	0.06	2.00	1.00	0.040	0.14	16.00-19.00	9.00-11.00	...	...	1.30-2.40 Cu
30452	304 HN(b)	0.08	2.00	1.00	0.045	0.030	18.00-20.00	8.00-10.50	...	0.16-0.30	...
30500	305	0.12	2.00	1.00	0.045	0.030	17.00-19.00	10.00-13.00	...	...	...
30900	309	0.20	2.00	1.00	0.045	0.030	22.00-24.00	12.00-15.00	...	...	...
30908	309S	0.08	2.00	1.00	0.045	0.030	22.00-24.00	12.00-15.00	...	...	...
31000	310	0.25	2.00	1.50	0.045	0.030	24.00-26.00	19.00-22.00	...	...	...
31008	310S	0.08	2.00	1.50	0.045	0.030	24.00-26.00	19.00-22.00	...	...	...
31600	316	0.08	2.00	1.00	0.045	0.030	16.00-18.00	10.00-14.00	2.00-3.00	...	...
31603	316L	0.030	2.00	1.00	0.045	0.030	16.00-18.00	10.00-14.00	2.00-3.00	...	...
31620	316F	0.08	2.00	1.00	0.20	0.10(a)	17.00-19.00	12.00-14.00	1.75-2.50	...	...
31700	317	0.08	2.00	1.00	0.045	0.30	18.00-20.00	11.00-15.00	3.00-4.00	...	...
31703	317L	0.030	2.00	1.00	0.045	0.030	18.00-20.00	11.00-15.00	3.00-4.00	...	...
32100	321	0.08	2.00	1.00	0.045	0.030	17.00-19.00	9.00-12.00	...	...	5 × C min Ti
34700	347	0.08	2.00	1.00	0.045	0.030	17.00-19.00	9.00-13.00	...	...	10 × C min Nb
34720	347F(b)	0.08	2.00	1.00	0.045	0.18-0.35	17.00-19.00	9.00-12.00	...	...	10 × C-1.10 Nb
34723	347FSe(b)	0.08	2.00	1.00	0.11-0.17	0.030	17.00-19.00	9.00-12.00	...	...	10 × C-1.10 Nb; 0.15-0.35 Se
38400	384	0.08	2.00	1.00	0.045	0.030	15.00-17.00	17.00-19.00	...	...	...
N08020	20Cb-3(e)	0.07	2.00	1.00	0.045	0.035	19.00-21.00	32.00-38.00	2.00-3.00	...	8 × C-1.00 Nb; 3.00-4.00 Cu

(continued)

Note: All compositions include Fe as balance. (a) Minimum, rather than maximum wt%. (b) Designation resembles AISI type, but is not used in that system. (c) Common trade name, rather than AISI type. (d) Trade name of Crucible Inc. (e) Trade name of Carpenter Technology Corporation. (f) Trade name of Al-Tech Corp. (g) Trade name of Armco Inc.

Table 1 (continued)

UNS designation	AISI type	Composition, wt% max								
		C	Mn	Si	P	S	Cr	Ni	Mo	N	Others
Duplex alloys											
S31803	2205(c)	0.030	2.00	1.00	0.030	0.020	21.0-23.0	4.50-6.50	2.50-3.50	0.08-0.20	...
S32550	Alloy 255(c)	0.04	1.50	1.00	0.04	0.03	24.0-27.0	4.50-6.50	2.00-4.00	0.10-0.25	1.50-2.50 Cu
S32900	329	0.20	1.00	0.75	0.040	0.030	23.00-28.00	2.50-5.00	1.00-2.00	...	...
S32950	7-Mo Plus(e)	0.03	2.00	0.60	0.035	0.010	26.0-29.0	3.50-5.20	1.00-2.50	0.15-0.35	...
Precipitation-hardenable alloys											
S13800	PH13-8 Mo(g)	0.05	0.20	0.10	0.010	0.008	12.25-13.25	7.50-8.50	2.00-2.50	0.01	0.90-1.35 Al
S15500	15-5PH(g)	0.07	1.00	1.00	0.040	0.030	14.00-15.50	3.50-5.50	...	...	0.15-0.45 Nb; 2.50-4.50 Cu
S15700	15-7PH(g)	0.09	1.00	1.00	0.040	0.030	14.00-16.00	6.50-7.25	2.00-3.00	...	0.75-1.50 Al
S17400	17-4PH(g)	0.07	1.00	1.00	0.040	0.030	15.50-17.50	3.00-5.00	...	...	0.15-0.45 Nb; 3.00-5.00 Cu
S17700	PH 17-7(g)	0.09	1.00	1.00	0.040	0.040	16.00-18.00	6.50-7.75	...	...	0.75-1.50 Al
S35000	633(b)	0.07-0.11	0.50-1.25	0.50	0.040	0.030	16.00-17.00	4.00-5.00	2.50-3.25	0.07-0.13	...
S35500	634(b)	0.10-0.15	0.50-1.25	0.50	0.040	0.030	15.00-16.00	4.00-5.00	2.50-3.25	0.07-0.13	...
S44000	Custom 450(e)	0.05	1.00	1.00	0.030	0.030	14.00-16.00	5.00-7.00	0.50-1.00	...	8 × C min; 1.25-1.75 Cu
S45500	Custom 455(e)	0.05	0.50	0.50	0.040	0.030	11.00-12.50	7.50-9.50	0.50	...	0.10-0.50 Nb; 1.50-2.50 Cu 0.80-1.40 Ti
S66286	A286(c)	0.08	2.00	1.00	0.040	0.030	13.50-16.00	24.0-27.0	1.00-1.50	...	0.35 Al; 0.0010-0.010 B 1.90-2.35 Ti; 0.10-0.50V

Note: All compositions include Fe as balance. (a) Minimum, rather than maximum wt%. (b) Designation resembles AISI type, but is not used in that system. (c) Common trade name, rather than AISI type. (d) Trade name of Crucible Inc. (e) Trade name of Carpenter Technology Corporation. (f) Trade name of Al-Tech Corp. (g) Trade name of Armco Inc.

leum and petrochemical plants, textile plants, and the pharmaceutical and transportation industries. Some of these applications involve exposure to either elevated or cryogenic temperatures; austenitic stainless steels are well suited to either type of service. Properties of stainless steels at elevated temperatures are discussed in the article "Elevated-Temperature Properties" in this Volume. Properties at cryogenic temperatures are discussed in the article "Low-Temperature Properties."

Modifications in composition are sometimes made to facilitate production. For instance, basic compositions are altered to make it easier to produce stainless steel tubing and castings. Similar modifications are made for the manufacture of stainless steel welding electrodes; here, combinations of electrode coating and wire composition are used to produce desired compositions in deposited weld metal.

Designations for Stainless Steels

In the United States, wrought grades of stainless steels are generally designated by the American Iron and Steel Institute (AISI) numbering system, the Unified Numbering System (UNS), or the proprietary name of the alloy. In addition, designation systems have been established by most of the major industrial nations (Ref 2). Of the two institutional numbering systems used in the U.S., AISI is the older and more widely used. Most of the grades have a three-digit designation; the 200 and 300 series are generally austenitic stainless steels, whereas the 400 series are either ferritic or martensitic. Some of the grades have a one- or two-letter suffix that indicates a particular modification of the composition.

The UNS system is a broader-based system that comprises a list of all metallic materials, including stainless steel. This system includes a considerably greater number of stainless steels than AISI, because it incorporates all of the more recently developed stainless steels. The UNS designation for a stainless steel consists of the letter *S*, followed by a five-digit number. For those alloys that have an AISI designation, the first three digits of the UNS designation usually correspond to an AISI number. When the last two digits are 00, the number designates a basic AISI grade. Modifications of the basic grades use two digits other than zeroes. For stainless steels that contain high nickel contents (~ 25 to 35% Ni), the UNS designation consists of the letter *N* followed by a five-digit number. Examples include N08020 (20 Cb-3), N08024 (20Mo-4), N08026 (20Mo-6), N08366 (AL-6X), and N08367 (AL-6XN). Although classified as nickel-base alloys by the UNS system, the aforementioned materials constitute the "superaustenitic" category of stainless steels as described below in the section on "Classification of Stainless Steels."

Table 1 provides the compositional limits for selected stainless steels, listed by UNS and AISI type designations and separated into the basic families described below. Where AISI type designations are not available, common trade names are listed. These names, the third commonly used identification of stainless steels, have often become the popular means of identifying a particular alloy. More thorough listings of chemical compositions for wrought, cast, and P/M stainless steels can be found in the articles "Metallurgy and Properties of Wrought Stainless Steels," "Metallurgy and Properties of Cast Stainless Steels," and "Powder Metallurgy Stainless Steels" in this Volume.

Classification of Stainless Steels

Stainless steels can be divided into five families. Four are based on the characteristic crystallographic structure/microstructure of the alloys in the family: ferritic, martensitic, austenitic, or duplex (austenitic plus ferritic). The fifth family, the precipitation-hardenable alloys, is based on the type of heat treatment used, rather than microstructure.

Ferritic stainless steels are so named because their body-centered-cubic (bcc) crystal structure is the same as that of iron at room temperature. These alloys are magnetic and cannot be hardened by heat treatment. In general, ferritic stainless steels do not have particularly high strength. Their annealed yield strengths range from 275 to 350 MPa (40 to 50 ksi), and their poor toughness and susceptibility to sensitization limit their fabricability and the usable section size. Their chief advantages are their resistance to chloride stress-corrosion cracking, atmospheric corrosion, and oxidation at a relatively low cost.

Ferritic stainless steels contain between 11 and 30% Cr, with only small amounts of austenite-forming elements, such as carbon, nitrogen, and nickel. Their general use depends on their chromium content.

The low-chromium (11%) alloys (S40500 and S40900, the latter being the most widely used ferritic stainless steel) have fair corrosion and oxidation resistance and good fabricability at low cost. They have gained wide acceptance for use in automotive exhaust systems.

The intermediate-chromium (16 to 18%) alloys (S43000 and S43400) are used for automotive trim and cooking utensils. These alloys are not as readily fabricated as the lower chromium alloys because of their poor toughness and weldability.

The high-chromium (19 to 30%) alloys (S44200 and S44600), which are often referred to as superferritics (Fig. 1), are used for applications that require a high level of corrosion and oxidation resistance. These alloys often contain either aluminum or molybdenum and have a very low carbon content. Their fabrication is possible because of special melting techniques that can achieve very low carbon con-